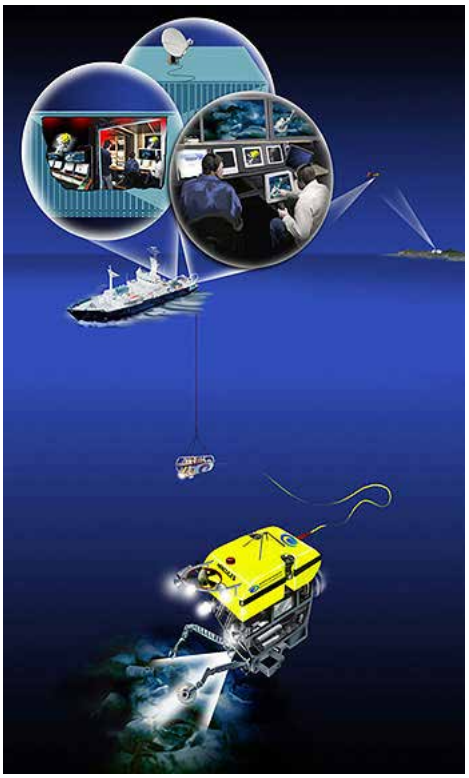
Introduction to Telepresence

Almost three decades ago, Dr. Robert Ballard envisioned the use of satellite technology to allow scientists, teachers and students on shore access to data and images from ships at sea in real-time. This concept of access in real-time is called telepresence technology. Although it continues to evolve, telepresence technology has advanced at a rapid pace in recent years, providing a virtual portal into the excitement of oceanographic discoveries and demonstrating the importance of exploring our largely unknown ocean. NOAA's Office of Ocean Exploration and Research (OER) partnered with Dr. Ballard at the Institute for Exploration (IFE) and the University of Rhode Island's (URI) Inner Space Center (ISC) to develop a new paradigm for ocean exploration that takes telepresence to a new level with the goal of increasing the pace, scope and efficiency with which we are able to explore the ocean world.

Telepresence is simply a group of technologies that enable people to observe and interact with events at remote locations. On board the NOAA Ship *Okeanos Explorer*, the foundation for telepresence is advanced broadband satellite communication. Telepresence allows video and audio in real-time and other imagery to be transmitted from a remotely operated vehicle (ROV) at sea through satellites to the ISC at URI. From the ISC, these products are transmitted through the Internet to other scientists ashore located at Exploration Command Centers (ECCs). The ECCs are remote locations outfitted with special communications equipment, including consoles with plasma screens for viewing the video, as well as an Internet-enabled intercom system. The system enables scientists and others to converse simultaneously with the explorers at sea, and/or scientists at other ECCs located anywhere in the world. Currently, ECCs are located at the URI ISC; the NOAA/University of New Hampshire (UNH) Center for Ocean and Coastal Mapping (CCOM) Joint Hydrographic Center; the NOAA Pacific Marine Environmental Laboratory (PMEL) in Seattle; at NOAA in Silver Spring, Maryland; and at the Stennis Space Center in Mississippi.

From the Ship to the Sky

The most prominent piece of communications equipment aboard the *Okeanos Explorer* is the 4.2 m diameter dome that houses the ship's 3.7-meter Very Small Aperture Terminal (VSAT) dish antenna. This antenna is the critical link between the *Okeanos Explorer* and the satellites that relay information between the ship and the ECCs, as well as the ISC. Computers and hardware included in the antenna system make constant adjustments that compensate for the ship's heave, roll and pitch to keep the antenna pointed toward the appropriate communications satellite. Radio transmitters and receivers connected to the VSAT antenna



Telepresence technology uses satellite technology and the internet to transmit data and video in real-time from remotely operated vehicles (ROVs) working at depth, to a shore-based hub at the University of Rhode Island, which then sends this data to a variety of receiving stations on shore. Image courtesy of Paul Oberlander, Woods Hole Oceanographic Institution.
http://oceanexplorer.noaa.gov/explorations/07blacksea/background/telepresence/media/shipveh.html

operate in the global C-band, using frequencies between 3.7 to 4.2 GHz for downlinks, and frequencies between 5.925 GHz to 6.425 GHz for uplinks (signals received from a satellite are downlinks; signals sent to a satellite are uplinks). These frequencies are in the microwave region of the electromagnetic spectrum. The satellites used by the *Okeanos Explorer's* telepresence system are 22,753.2 statute miles ("normal" miles, not nautical miles) above Earth's surface. At this altitude, the satellites' rotational speed matches the speed of Earth's rotation so they appear to remain in a fixed position when viewed from Earth's surface. For this reason, these satellites are called "geosynchronous."

Connecting ECCs to Each Other and to the *Okeanos Explorer*

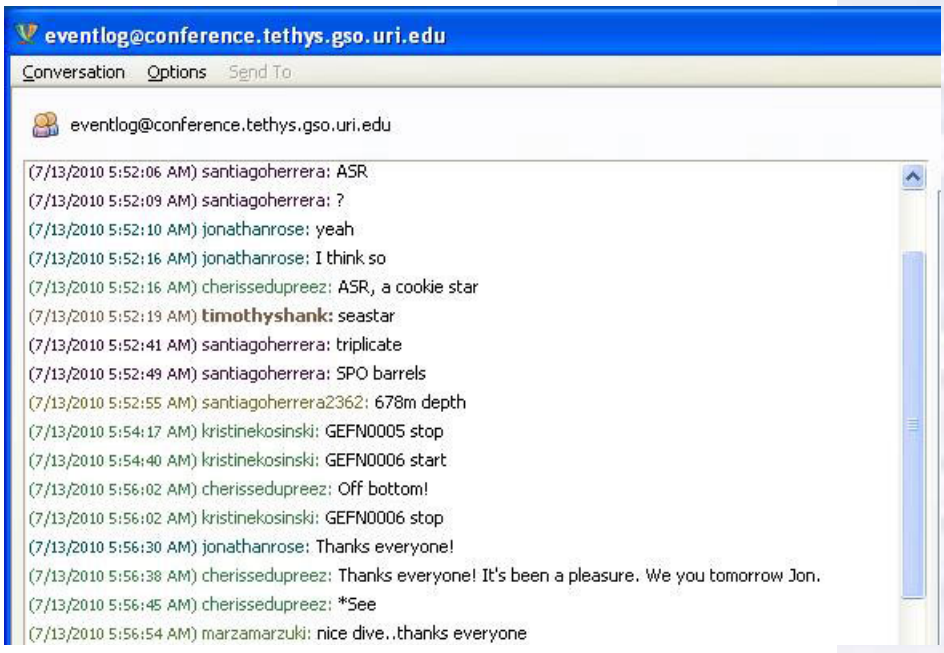
Real-time voice communications among scientists onboard the ship and among the ECCs are enabled by an Internet-based intercom system, which allows all participants, regardless of location, to easily communicate with all other participants. This voice communication between the *Okeanos Explorer* and shore-side ECC's uses a technology borrowed from the broadcast industry, an IP-enabled intercom system. This system leverages the *Okeanos Explorer's* Internet connectivity to connect all of the ship-based and shore-based intercom units located at the ECCs into a single system.

The "Eventlog": Another Telepresence Communication Tool

During expeditions, real-time voice communication is supplemented by a real-time text-based tool called the "Eventlog," which allows each science observer to write his or her personal observations to a common digital, or computer-based, log. Log entries can immediately be seen by all other users. All users on the ship and at the ECCs are encouraged to participate in the Eventlog, since each individual is potentially able to provide unique observations and insight into what all are observing for the first time through the "eyes" of the ROV. Ocean exploration is, by definition, multidisciplinary and as such, scientists with differing areas of expertise must be involved in the missions so as to be able to most accurately, completely, and effectively characterize exploration targets captured in the video streams of the ROV. The Eventlog software automatically "stamps" the date, time of entry, and author of each text observation on each entry. This simplifies post-cruise data, and video searches. The Eventlog tool leverages the same technology and standards-based protocols used on the Internet for Instant Messages (IM) and chatrooms.

Assembly the VSAT for the *Okeanos Explorer* in the Fairhaven Ship Yard in Bellingham, WA, 2007. Image courtesy of Installation and Operation Manual for Sea Tel Model14600-75 Phase Matched C-Band TX/RX Antenna.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/apr13/media/apr13-2.html

Technicians work on the satellite antenna in the VSAT dome. Image courtesy of NOAA *Okeanos Explorer* Program, Galapagos Rift Expedition 2011.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/logs/hires/july11_update01_hires.jpg



INDEX 2010 participants used a real-time text-based collaboration tool called the "Eventlog" to communicate and make log entries about ongoing operations. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july09/media/ichat.html

Voice communication between the *Okeanos Explorer* and shore-side ECC's uses an IP-enabled intercom system. Here, scientists at the Seattle ECC communicate with participants on the ship and at the Jakarta ECC. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/seattle_rts_hires.jpg

A doctoral student with the MIT-WHOI joint program,was based at the Seattle ECC during the INDEX-SATAL 2010 Expedition. Image courtesy of Woods Hole Oceanographic Institution.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/ellie_seattle_hires.jpg

Data Management through Telepresence

In addition to video collected by the *Okeanos Explorer's* ROVs, other data are also transmitted via satellite back to shore for distribution, data management and archive purposes. Data collected by the EM302 multibeam array and the EK60 echosounder used to characterize the seafloor and water column are also sent to ECCs, along with CTD data to help scientists interpret observations in real-time from the seafloor. A multitude of other data is also sent to shore for during cruise and post-cruise processing. See the article entitled Careers Managing Scientific Information Aboard the NOAA Ship *Okeanos Explorer* at *http://oceanexplorer.noaa.gov/edu/oceanage/current_careers.pdf* for more information on managing data onboard the *Okeanos Explorer* using telepresence.

Building Scientific Intellectual Capital with Telepresence

Through direct communication of scientists located at the various ECCs with scientists and technicians on board the *Okeanos Explorer* during expeditions, a much broader realm of scientific expertise is brought to the exploration as soon as discoveries are made, and with much less of an investment in "person-at- sea" days than during most traditional oceanographic expeditions. Since the *Okeanos Explorer's* powerful satellite dome has high-bandwidth, a large amount of data can be transmitted from the ship to the ISC and ECCs in a short span of time, including three high-definition video feeds, as well as real-time voice communication Internet connections. High definition video transmissions use broadcast industry equipment to deliver high quality video with very little time delay. Even with intensive signal processing and the delays introduced by satellite and land-based links, video travels from the ROV at depths reaching 4,000 m to the ECCs thousands of miles away in an average of six seconds.

To the ECCs and Beyond

The ability to watch the live events aboard the *Okeanos Explorer* is not limited to those with access to an ECC. Capabilities today enable users to view live feeds from the *Okeanos Explorer* via the Internet on the *Ocean Explorer* website at *oceanexplorer.noaa.gov* during active expeditions to bring real-time ocean exploration science and the scientists behind it into classrooms, newsrooms, and living rooms, which opens new educational opportunities that are a major part of the *Okeanos Explorer's* mission for the advancement of knowledge.

Implementing telepresence is far from simple. However, the impact of telepresence is immeasurable. During INDEX-SATAL 2010, the maiden voyage of the *Okeanos Explorer*, approximately 20 scientists gathered at the ECC at the Pacific Marine Environmental Laboratory in Washington State (PMEL) as thousands of public onlookers from three countries, five time zones, distributed across thousands of miles, were able witness, discuss and document the incredible life and habitats residing at the bottom of the Indonesian Sea. As technologies continue to evolve, so too, telepresence capabilities for ocean exploration will continue to expand, bringing with them new ways of exploring and communicating about our little known ocean world.

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